Pt(111)-(100) Nanofaceted Model Electrocatalysts

Scientific Achievement

A novel approach of preparing a one-dimensional model system for nanoparticle catalysts is presented. Unlike the stepped surfaces prepared by vicinal cuts of low-index surfaces, our preparation method provides two low-index facets, (111) and (100), connected by edges in nanoscale proximity. This (111)-(100) faceted surfaces resemble much more closely the realistic nanoparticles which have cubooctahedral shape composed of low-index (111) and (100) facets and edges.

We studied oxygen reduction reactions, the most important reaction of fuel cell application because of its slow kinetics and large overpotential, on the nanofacets. Reduction of molecular oxygen (O_2) to oxygen ions ($2O^{-2}$), the most inefficient reaction in fuel-cell systems, takes place in several sequential steps on the surfaces of nanoparticle catalysts. Reaction steps in the sequence are more efficient on (111) than on (100) facet, while an opposite is true for activation steps. With nano-science tools, we created a model nano-catalyst. The most fascinating discovery of our study is that (100) activates reaction species and (111) promotes them to react. (111) would starve without (100), and (100) be self-poisoned without (111). This "Division of Labor" is possible because the reactants can cross over between the facets that are in nanoscale proximity.

Significance

The discovery, not limited to fuel-cell catalysts, opens new doors for exploiting nanoscale structuring to make better catalysts. As the next step, nano-fabricated Array Model Catalysts, array model catalysts can be fabricated by self-assembly or with modern lithography techniques such as focused-ion-beam or electron-beam lithography. We successfully fabricated array catalysts where millions of nanoparticles are all perfectly registered, identical in size, shape, and orientations. These array model catalysts allow molecular-level study of nanoparticles by experimental techniques developed for single-crystal surfaces or large-surface area catalysts. [V. Komanicky, A. Menzel, K. C. Chang, H. You, *J. Phys. Chem*. B, 109, (2005), 23543; ibid, 23550]

Performers

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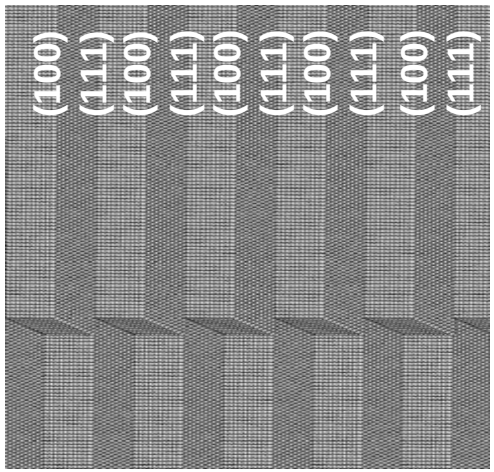
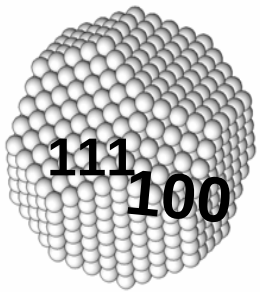
We can prepare a platinum surface consisting of (100) and (111) facets joined together by the edge



which resembles nanoparticle surfaces.



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Next Step: Nano-fabricated Array Model Catalysts

Array model catalysts can be fabricated by self-assembly or with modern lithography techniques such as focused-ion-beam or electron-beam lithography. We successfully fabricated array catalysts where millions of nanoparticles are all perfectly registered, identical in size, shape, and orientations. These array model catalysts allow molecular-level study of nanoparticles by experimental techniques developed for single-crystal surfaces or large-surface area catalysts.

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